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MODERN TECHNIQUES AND INSTRUMENTS FOR SURVEYS AND MAPPING

By Geo. D. WHITMORE,
Chief Topographic Engineer,
U.S. Geological Survey,
Washington, D.C.

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MODERN TECHNIQUES AND INSTRUMENTS FOR SURVEYS AND MAPPING

by Geo. D. Whitmore
Chief Topographic Engineer
U.S. Geological Survey
Washington, D. C.

1. There can be no question that orderly evaluation and efficient utilization of any country's resources require certain geographic and topographic information in the form of reliable maps based on ground and aerial survey data. In those countries where existing surveys and maps are meager, the initial task may be the preparation of temporary map substitutes, or small-scale maps of a reconnaissance nature, based almost entirely on aerial photography and other air-survey data. In those countries where national surveying-mapping programs are already in progress, and a surveying-mapping establishment already exists, the initial task may be rapid expansion and modernization of the program and the establishment. In any case, the use of some of the modern techniques and instruments that have become available during recent years will be involved. It is the purpose of this paper to describe briefly some of these modern developments, and to indicate in general terms when they might be used to advantage. References to literature describing the principal items in greater detail are given in the footnotes for those who desire more complete information.

2. Although the emphasis in this paper is on modern techniques and instruments, it is well to heed a note of caution at the outset: i.e., a technique or instrument will not necessarily be universally applicable, or best satisfy all needs, only because it is the most modern. To determine, for any specific national program or local project, which of several applicable procedures is most advantageous, whether old or new, requires a thorough understanding of 1) the available procedures, 2) the users' requirements, and 3) the factors that tend to limit the choice of procedures. Among the more important of the requirements and factors that must be considered are: the type of survey or map needed; the map scales to be used; the degree of accuracy required for control surveys[1] and mapping[2]; the size and shape of the area to be covered; the allowable time schedule; the available funds; any unusual characteristics of terrain, climate, or forest foliage; and the technical competence of available personnel.

3. The following paragraphs 4 to 30 deal with specific techniques or instruments that might be included as steps in any selected over-all procedure. For convenience, these items are grouped under four principal headings, namely, control surveys, aerial photography, photogrammetric procedures, and preparing maps for reproduction. Although no procedure would include all of the techniques and instruments mentioned, it is likely that any over-all procedure which might be adopted would necessarily include some of them.

CONTROL SURVEYS

4. For control surveys of any degree of accuracy or for any purpose, there

[1] Horizontal specifications are given in: Specifications for fundamental geodetic networks, Travaux de l'Association International de Geodesie, 21, 53-57 (1962). Vertical specifications are given in: International resolutions relative to levelling of high precision, Bulletin Geodesique 61, 176-185 (1939).

[2] Symposium on the National Map Accuracy Standards, Surveying and Mapping, 20, 427-457 (1960).

are now available new instruments and techniques that were unknown a generation ago, and which, under certain conditions, will result in the work being accomplished faster, more accurately, and at lower costs.

5. Distance measurements for control surveys are now accomplished mainly by new scientific instruments which exploit the modern techniques of electromagnetic wave transmission and electronics. These instruments can be used to advantage whenever there is a continuing control-survey program involving numerous precise measurements of triangulation base lines or traverse courses.

(a) In the geodimeter,[3] developed in Sweden, a modulated light beam is directed from apparatus set up at one survey station to a reflector set up at a second station. The distance between the two stations is determined as a function of the velocity of light and the phase relationships between the emitted beam and the reflected beam at various modulation frequencies. This operation requires clear weather, darkness (although the latest model permits short measurements in daylight), and an unobstructed path between the two stations. Several different models are available, the smallest being suitable for distances as short as 2 or 3 miles, while the largest can be used for precise base lines of as much as 30 miles.

(b) In the tellurometer,[4] developed in South Africa, a modulated continuous-wave radio signal is transmitted from a master unit at one survey station to a remote unit at a second station, where it is, in effect, received and retransmitted to the first unit. The distance is the product of the measured transit time and the known velocity of radio waves. The tellurometer can be operated in daylight or darkness and can penetrate haze, smoke, fog, clouds, light rain, and a limited amount of foliage. Its operation is affected by reflections from nearby moving objects, such as waving grass or moving vehicles. The tellurometer is used to best advantage for measurements in the range of 10 to 25 miles, although it has been used successfully up to 40 miles under good conditions, and, if great accuracy is not necessary, can be used on distances as short as one mile or less.

(c) The electrotape,[5] an American development, operates on the same basic principle and has the same applications as the tellurometer, although it differs in details.

6. In the measurement of angles, the standard instrument of today, by almost universal acceptance, is the optical-reading theodolite, an instrument which has ultra-precise graduations on glass circles that are read to a fraction of a second of arc by means of a special optical micrometer. These theodolites are fully as accurate as the older, heavier, more cumbersome instruments. The use of optical-reading theodolites is therefore generally regarded as advantageous in all types of surveys involving measurement of angles.

7. A new portable surveying tower[6] for elevating theodolites, signal lights and electronic distance-measuring instruments to any height up to some 80 feet above the ground, is being used experimentally in the United States. Each unit consists of the usual two tripod towers--an outer one for the observer, and an independent inner one for the instrument. In comparison with towers previously available, the new towers, fabricated from tubular aluminum, are much lighter in weight, and can be assembled and erected more rapidly by only two men. The entire double-tower unit can be transported trailer-fashion behind a light truck, in which case the trailing wheels are attached to the outer tower and remain in place when the tower is erected, or it can be moved by helicopter. Indications are that this type of portable tower

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[3] Bergstrand, E., Measurement of distances by high frequency light signalling, Bulletin Geodesique, 11, 8-92 (1949).

[4] Wadley, T.L., The tellurometer system of distance measurement, Empire Survey Review, 14, 100-111, 146-160 (1957).

[5] Heape, R.E.,Jr., Electrotape: electronic distance measuring equipment, Surveying and Mapping, 22, 265-9 (1962).

[6] Whitmore, G.D., Portable triangular surveying tower, Civil Engineering 32, 69 (1962).

will be advantageous, on surveys of second- and lower-order accuracies, in terrain where the local obstructions are not more than about 70 feet in height.

8. Extensive experiments are underway in the United States with a technique for extending ground-survey control for mapping, which utilizes a combination of ground and air measurements. The method involves distance measurements and horizontal and vertical angle measurements from at least two, and preferably three, strategically located existing control stations to a helicopter as it hovers vertically over each desired new control point.[7] Accurate hovering is facilitated by a newly developed "hoversight" which faithfully indicates the vertical to the pilot, so that he can see when he is directly over the ground point. The helicopter hovers at a height just great enough so that it can be seen from the occupied ground stations, and a special plumb-line cable and drum are used to measure the hovering height. When the pilot signals by radio that he is over the point, azimuths and vertical-angle readings are made to a target light on the helicopter from the theodolites at the ground stations. At the same time, electronic distance measurements are made by a hydrodist (similar to tellurometer) installation, from a master unit at each ground station to a remote unit in the aircraft. Preliminary tests indicate that this technique will be advantageous in forested areas on control where third-order positions and fourth-order elevations are sufficient.

9. For determining differences of elevation accurately, the most up-to-date instrument is the self-compensating level.[8] This instrument operates so that, after it has been leveled only approximately, the collimation axis is automatically made exactly level by a gravity-sensitive compensator, similar in principle to the pendulum. This feature speeds operations by reducing the need for great care in instrument setup and eliminating the need for frequent releveling. The new level thus is generally regarded as advantageous, particularly for leveling of second- and third-order accuracies. For planetable surveys, self-leveling alidades, called pendulum alidades,[9] are also now available.

10. On projects covering large areas, when elevation differences not better than fourth-order accuracy are needed, the use of an American instrument utilizing the pendulum principle, and called the elevation meter[10] may sometimes be economical. The equipment is mounted in a four-wheel-drive automotive vehicle provided with four-wheel steering. As the vehicle proceeds along the road, an electromagnetic field acts on a very sensitive pendulum in such a way as to generate an electrical signal whose strength is proportional to the sine of the angle of slope. Another electrical signal is generated by a revolution counter connected to a special fifth wheel which measures each small increment of distance traveled. By means of an electronic integrator, the two signals are automatically combined into a continuous record of the difference of elevation from an initial starting point. Proceeding at moderate speeds over readily passable roads, the elevation meter can produce about 50 to 100 miles of fourth-order leveling per day. It can be used for rapidly determining approximate elevations, accurate within 10 to 30 feet, on long cross-country lines, but it can also provide elevations accurate to within two feet, if all lines are within closed circuits, if some main lines are double run, and if all closures are properly distributed mathematically. This equipment, however, whether leased or purchased, would prove to be economical only on projects which cover relatively large areas, and which have a network of suitable roads.

11. The use of modern electronic digital computers can remove much of the drudgery from repetitive survey computations. Furthermore, the work can be produced

[7]Buckmaster, J.L., Loving, H.B., and Dando, T.O., Airborne control system, U.S. Geol. Surv. Prof. Paper 450-E (1962) in preparation.

[8]Ellenberger, H., Das automatische Nivellier, Uberblick uber den Stand der Entwicklung, Allgemeine Vermessungs-Nachrichten, Jahrgang 1955, 325-334.

[9]Bolter, Ward H., The Self-Indexing Alidade, Surveying and Mapping, 16, 157-163 (1965).

[10]Burger, T.C., Use of elevation meter in topographic surveying, Surveying and Mapping, 21, 481-7 (1961). See also Speert, J.L., New elevation meter for topographic surveys, U.S. Geol. Surv. Prof. Paper 450-B, 141-2 (1962).

very rapidly, and often at large savings in costs. Once a computer program has been prepared for a given type of computation, it is only necessary to change the input data for each particular case; the same program can be used again and again. Computer programs have been prepared for such survey tasks as computation and adjustment of traverse and triangulation. The possible economy or other advantage of such a computer should always be carefully investigated when several man-years of work would be required by the older procedures. While it is true that very few surveying programs by themselves would justify the high cost of full-time lease or purchase of such a computer, it may often be profitable to hire such service on an hourly basis.

12. For each project, the most economical and satisfactory means of transporting men and equipment to the places where surveying observations are to be made must be carefully selected. For terrain where access is difficult, the possible use of helicopters[11] should not be overlooked. Experience shows that, although the hiring of helicopters with pilots and mechanics is very costly, the time gained will often result in lower over-all costs. Furthermore, when rapid completion of the work is a requirement and access is difficult, helicopters may be a necessity regardless of cost. It is also to be noted that the use of helicopters usually would not be efficient without portable two-way radios. In fact, such radio communication is a practical necessity in many other modern surveying procedures, as in electronic distance measuring.

AERIAL PHOTOGRAPHY

13. Aerial photographs and other air-survey data are available in a variety of forms, each of which has its uses, depending on the kind of product desired and the conditions pertaining to the particular project at hand. Aerial photography should be specially designed for each different area or individual project; for example, in some cases, two or more different types of photography, at two or more different altitudes may be required. In every case, the planning should provide for all air-survey data to be fully useful, not only for the desired long-range products, but also for any temporary products that may be necessary, and for all data to be fully compatible with the available photogrammetric equipment and techniques.

14. In the United States, the two types of aerial camera lenses currently in most common use are the 210-mm normal-angle (65°) and the 153-mm wide-angle (90°). Recently, there have become available new 88-mm super-wide-angle (120°) cameras[12] which, in comparison with the wide-angle camera, offer more economical coverage at a more favorable base-height ratio. The larger coverage per model reduces ground-survey control requirements, and the more favorable base-height ratio gives better angles of ray intersections, which improves the accuracy of height determinations. A possible disadvantage, however, is that super-wide-angle photography at the same altitude would be at a much smaller scale. Also, if the terrain is covered with dense forests, the ground between the trees is visible less frequently than in the narrower-angle photography. Likewise, there are likely to be more invisible areas in rugged terrain. Nevertheless, for many mapping requirements super-wide-angle photography may offer important advantages.

15. Some notable advantages have been gained during the past 12 years by a twin-low-oblique camera arrangement[13] and related plotting equipment. The cameras are usually the same 153-mm wide-angle cameras used in vertical photography, but two are used together in a precisely synchronized arrangement. When the lens-to-lens axis of the camera couple is parallel to the line of flight, the product is called convergent photography; when the axis is perpendicular to the flight line, it is called transverse photography. Convergent photography, having an air base about twice as long as that for comparable vertical photography, has some of the advantageous features of super-wide-angle photography and has been widely used in the preparation of

[11] Fitzgerald, G., Helicopter revolutionizes topographic mapping of remote areas, Civil Engineering, 24, 798-801 (1954).

[12] Wey, O., Small-scale mapping, Photogrammetric Engineering, 27, 148-50 (1961).

[13] Hopkins, B.T., Radlinski, W.A., Thompson, M.M., Twin low-oblique photography and the twinplex plotter, Geological Survey Circular 222 (1952).

topographic maps of standard accuracy. In transverse photography, determination of elevation and position in the stereomodels is less accurate, but there is a considerable increase in the width of stereoscopic photo coverage perpendicular to the flight line. Thus transverse photography is well suited for reconnaissance mapping. Twin-low-oblique photography has certain minor disadvantages, as compared to vertical, including the need for a special camera mount and corresponding alterations to the fuselage of the aircraft, and the need to make transformed prints if photographs having uniform scale are required. For an organization newly considering the use of photography having a large base-height ratio, super-wide-angle photography will probably hold more promise. The intriguing possibilities of using super-wide-angle cameras in a twin-low-oblique arrangement should not be overlooked for small-scale mapping, and research in this direction can surely be expected.

16. There are now available several types of dimensionally stable film bases[14] produced from either polycarbonate or polyester plastics, which, in comparison with acetate film, have only about one-third the humidity and thermal coefficients of linear expansion, and far less differential distortion. For ultra-precise work, such as analytical aerotriangulation, a reseau may still be required with the new film base, but for most purposes the distortions due to film instability can be ignored.

17. Infrared photography[15] has been improved recently with the development of better emulsions and new camera lenses specifically designed to achieve optimum photographic quality with infrared film. An important advantage of infrared photography is its ability to penetrate atmospheric haze. It is also well known that water features, tree types, vegetation classifications, and soil-structure differences are more readily distinguishable on infrared photographs than on conventional black-and-white. It may therefore be economical, in some instances, to procure infrared photography as an aid in interpretation, in addition to the usual black-and white photography.

18. When aerial photography is required for an area having suitable flight maps, flight navigation usually is carried out by visual comparison of the ground and the flight map. If there are no suitable flight maps, a navigation system based on certain electronic and wave phenomena may be used. Any one of several electronic tracking methods[16] (including Shoran, Hiran, Raydist, Decca, or the latest development Shiran) can be used to obtain the position of each photographic exposure station with respect to two or more fixed ground stations, or to keep the aircraft on a predetermined flight path. These methods are feasible when ground stations can be occupied without excessive difficulty. The Doppler system,[17] which is entirely airborne, is suitable for air navigation over extensive areas where the difficulty of access makes establishment of ground stations impractical or too costly.

19. When approximate elevations of the ground trace of the flight line would be helpful, use of the radar altimeter[18] should be considered. This is a terrain-clearance instrument, entirely airborne, which continuously determines height of aircraft above the ground by "bouncing" a radio beam off the ground beneath. An automatic recorder then plots the profile of the ground along the aerial flight path with respect to the isobaric surface. The difference between aneroid elevations and

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[14] Calhoun, J.M., Adelstein, P.Z., Parker, J.T., Physical properties of Estar polyester base aerial films for topographic mapping, Photogrammetric Engineering 27, 461-70 (1961).

[15] Swanson, L.W., Photogrammetric surveys for nautical charting, use of color and infrared photography, Photogrammetric Engineering 26, 137-141 (1960).

[16] International Symposium on Electronic Distance-Measuring Techniques, Journal of Geophysical Research, vol. 65, 461-528 (1960).

[17] Meier, H., The use of Doppler radar in present and future mapping operations, Photogrammetric Engineering, 25, 632-5 (1959).

[18] Slama, C.C., Evaluation of an APR system for photogrammetric triangulation of long flights, Photogrammetric Engineering, 27, 62-78 (1961).

tne official vertical datum for the area, such as mean sea level, may be determined by having the aircraft fly over a suitable feature of known elevation, such as a body of water or an airport, whenever convenient. This method can yield ground elevations with accuracies in the range from 5 feet to 50 feet.

20. During the past few years there has been intensive development of various all-weather sensing devices,[19] including PPI (plan position indicator) radar, SLR (side-looking-radar), and the infrared sensors, as well as the Doppler radar and radar altimetry devices already mentioned. The primary advantage of these sensors is that they are operative day or night and in all weather. An important advantage of PPI is its ability to establish a uniform horizontal scale with an accuracy acceptable for reconnaissance charting purposes. PPI photography is at a very small scale and its resolution is weak, while SLR strip photography is at a much larger, though less uniform, scale with much better resolution; hence PPI and SLR are best used jointly to obtain the best combination of scale and resolution. The sensor devices make it possible to get fast, economical coverage for large expanses of territory, so that small-scale planimetric maps can be rapidly produced for preliminary planning or for flight maps for standard photography. It must be remembered, however, that radar altimetry must be included in the system if elevation data are required. In view of these factors, it is evident that the sensing devices are essentially applicable for extensive reconnaissance-survey data rather than for conventional air-survey data for standard mapping.

PHOTOGRAMMETRIC PROCEDURES

21. A variety of photogrammetric techniques and instruments are available for converting aerial photographs and other source data into maps or survey data. These range from simple procedures for results of relatively low precision, to elaborate systems for products of high accuracy. In any case, the combination of aerial source data, photogrammetric equipment and operational procedures must be compatible in every respect. As the well-established procedures are fully described in an extensive body of literature,[20] only certain of the recent developments will be noted in this paper.

22. Stereoscopic plotting instruments, which are the means by which modern photogrammetric techniques are used for the extraction of survey data and for the actual plotting of map detail, have been improved tremendously through an endless series of inventions and modifications that has now been going on for some 30 years. Although there are wide differences in the mechanical details, practically all stereoscopic mapping instruments are composed of 3 principal elements: 1) a projection system for orienting and projecting photographs stereoscopically, 2) a viewing system to give the observer the impression of a miniature model of the terrain, and 3) a measuring system for determining horizontal and vertical distances in the model. In western Europe there has been much emphasis on the so-called "first-order plotters," which are generally of an extremely complex design and capable of very high quality work, but which are also quite costly. American emphasis has been on the more economical, although somewhat less accurate and versatile, plotters of the multiplex type, which operate on the principle of simple optical projection and direct viewing. The original multiplex itself, with its small-size diapositives and inferior illumination, is now outmoded and has largely given way to its successors which use larger diapositives made practical mainly by improved lighting systems. The selection of stereoscopic plotting instruments for a photogrammetric facility should be based on the nature of the long-range surveying-mapping program. In many instances, a diversity of instruments is required. For this reason, some surveying-mapping organizations, on both sides of the Atlantic, are equipped with both first-order and lower-order instruments, although the emphasis may be on one

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[19] Symposium, Infrared and radar photo interpretation, Photogrammetric Engineering, 26, 610-656 (1960).

[20] American Society of Photogrammetry, Manual of Photogrammetry, 1952. This manual contains a list of publications in the field of photogrammetry.

or the other. Meanwhile, the current situation in instrumentation is marked by two principal trends: a) accelerated development of super-wide-angle equipment, and b) automation of plotting equipment.

23. Several kinds of stereoscopic plotters designed to utilize super-wide-angle photographs have been produced, both in Europe and the United States. The American instruments follow the general principles of the multiplex, but have improved projectors such as the ER-55 and Kelsh types. In Europe, both multiplex-type and autograph-type plotters for super-wide-angle photography are now available. At least one of the autograph-type instruments accommodates both wide-angle and super-wide-angle photography, which could be an important consideration for a new photogrammetric facility, as it would permit the same instruments to utilize either type of photography.

24. Several new techniques and instruments for aerotriangulation have been developed during recent years. These are all aimed at increasing the density of control points beyond that available from existing ground surveys, or with only a minimum amount of new ground surveys.

(a) The simplest of the new techniques is the stereotemplet method[21] for extending horizontal control. It differs from conventional radial triangulation techniques in that the stereotemplet is representative of the horizontal plot of a stereoscopic model rather than of a single photograph. Hence, it contains no significant displacements due to relief or tilt. This is probably the most economical procedure for horizontal control extension for maps at scales as large as 1:25,000 that are intended to conform to standard accuracy requirements.

(b) The Jerie-ITC mechanical analog computer,[22] developed in Holland, is a unique system of mechanical devices for determining, by separate horizontal and vertical adjustments, the most accurate positions and elevations of pass points within a block of several previously bridged strips of photographs. The accuracy of the horizontal positions obtained by this method was found in an American experiment to be slightly better than that obtained by the stereotemplet method, but the operation was more costly. On a vertical test area, the adjustment resulted in a mean square error of 3 feet and a maximum error of 8 feet in the elevations of pass points.

(c) Analytical aerotriangulation[23] has been given new impetus by the advent of a wide variety of electronic computers. Several different computational procedures have been devised, both in Europe and North America, not only for the block adjustment of several previously bridged strips, but also for the entire photogrammetric triangulation operation, starting with measurements of photoimage coordinates, through use of new stereocomparators and photo-point transfer devices. Although its economy is yet to be proved, the analytical approach has a great potential as a means of developing and adjusting blocks of horizontal and vertical control, and further developments may come rapidly. At this stage, however, it usually would not be advisable for a new organization to undertake a program of analytical aerotriangulation without first becoming proficient in the more established methods.

25. In a new American process, perspective photographs can be converted to equivalent orthographic photographs, called orthophotographs[24]. This product contains no significant displacements caused by tilt or relief and therefore all imagery

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[21] Scher, M.B., Stereotemplet triangulation, Photogrammetric Engineering 21, 655-663, (1955).

[22] Jerie, H.G., Block adjustment by means of analog computers, Photogrammetria, 14, 161-176 (1957-1958).

[23] Harris, W.D., et al., Analytical aerotriangulation in the Coast and Geodetic Survey, Photogrammetric Engineering, 28, 44-69 (1962). See also Dodge, H.F., Analytical aerotriangulation by the direct geodetic restraint method, Photogrammetric Engineering, 25, 590-595 (1959).

[24] Southard, R.B., Orthophotography - its techniques and applications, Photogrammetric Engineering, 24, 443-451 (1958).

is in correct relative position and the scale is uniform throughout. Useful map substitutes may be made by mosaicking individual contiguous orthophotographs, at the same scale, into map format. Orthophotographs, either as prints of single models or as mosaics, have already been successfully used by geologists and other scientists in field investigations, as preliminary planimetric maps or map substitutes, as a medium for testing the horizontal position accuracy of existing maps, and as a means of facilitating certain map-revision operations.

26. Orthophotographs are produced on an American instrument called the orthophotoscope,[25] which combines conventional double-projection anaglyphic mapping equipment with a means of exposing a sensitized film incrementally, through a narrow slit in a movable screen on which the model is projected. The elevation of the film is continually varied according to the terrain; thus the film is differentially exposed by the projected blue image (the red is non-actinic), always at the correct elevation. Detailed plans for manufacture of the orthophotoscope can be supplied by the U.S. Geological Survey.

27. A promising Canadian instrument,[26] now under development by an American company, embodies a system of electronics and electromechanics which may be incorporated in a conventional plotting instrument to accomplish automatically the relative orientation of the projectors and, subsequently, the drawing of contour lines. Automation of photogrammetric instrumentation in another direction is exemplified by the use of modified mapping equipment in combination with electronic computing equipment to produce engineering data, such as earthwork quantities for highway location studies, directly from the stereoscopic model without requiring a complete topographic map as an intermediary.

PREPARING MAPS FOR REPRODUCTION

28. The greatest gains to be realized in preparing maps for reproduction have resulted from the procedure of scribing[27] on coated plastic sheets. The scribing medium is a thin transparent plastic sheet coated with a translucent but photographically-opaque paint, on which a facsimile of the original map is reproduced by photographic printing, using a special emulsion that has been applied directly on the coated surface. Map detail is engraved, or scribed, by cutting the required map lines and symbols through the coating, with each separate color of the final map being scribed on a separate plastic sheet. Each scribed sheet is, in effect, a negative, from which a press plate can be prepared directly by contact printing. The scribing technique is also being increasingly used on planetable sheets in the field, and on photogrammetrically prepared map drawings.

29. "Stickup" lettering of high quality can now be provided quickly by new photo-type composing machines,[28] which produce positive film copy of the desired lettering from a wide variety of available type sizes and styles. The copy may be used as produced, but for normal use copies are reproduced on stripping film. Because these machines require a substantial investment they would probably not be economical, in comparison with conventional hand-set type and press-printed "stickup," except for large operations.

30. It is noteworthy that the negative scribing process facilitates production of certain useful by-products and interim materials. For example, a positive composite film is readily made by successively contact-printing each of the scribed color-separates plus the names overlay to a transparent film, and this in turn can be used to reproduce any number of ozalid-type monocolor prints. These are useful

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[25] Bean, R.K. and Thompson, M.M., Use of the Orthophotoscope, Photogrammetric Engineering, 23, 170 (1957).

[26] Hobrough, G.L., Automatic Stereo Plotting, Photogrammetric Engineering, 25, 763-769 (1959).

[27] Inter-Agency Committee on Negative Scribing, Report on Scribing, Part I, (1957); Part II, (1958-60); Part III, (1958) U.S. Geological Survey.

[28] The Lithographers Manual, vol. 1, Resources for copy preparation, pp. 4:93-114, Waltwin Publishing Co., New York (1958).

for checking and editing, and also as a provisional edition for map users until the final reproductions are press-printed. For final editing and proving, a color composite can be conveniently made in a properly-equipped photographic laboratory by preparing a photo-print in a series of contact exposures, using each scribed separate, in turn, with an appropriate color-producing emulsion that is applied on the sheet prior to each exposure, and which is completely processed before another emulsion for another color is applied.[29] This photo-print, in colors similar to those of the final published map, serves well as a low-cost substitute for a press-printed proof when only a few copies are required.

CONCLUSIONS AND RECOMMENDATIONS

31. In the foregoing pages, numerous modern procedures and instruments for surveys and mapping have been described in a general way, to show technical possibilities. The questions that remain for those concerned with the planning of new programs of surveying and mapping might well be these: Which of these procedures and instruments should be selected for the specific task at hand? Who should do the work? How long will it take? How much will it cost--for capital investment and annually for operations?

(a) It would be a useful service if a tabulation could be prepared to show exactly which procedures and instruments should be applied to any given surveying and mapping task, and how much money would be required to perform each phase of the work. Experience shows, however, that schedules of procedures and costs for unprecedented survey operations are tenuous things, because the factors entering into them are so varied and complex.

(b) Instead of including in this paper estimates of probable costs or manpower requirements, which may be out of step with local conditions, or recommending procedures that may not be applicable because of lack of trained personnel, lack of equipment, or other obstacles, it seems more appropriate to suggest the following over-all approach: That officials charged with formulating a surveying-mapping program should first consider all the methods that have a possible application to the specific task; and that they should then obtain as much information as possible about each applicable method from literature such as that referenced in this paper, and from consultations with recognized authorities, including conferences with appropriate agencies of other countries. It should then be possible to appraise the relative advantages and disadvantages of the various alternative procedures available and applicable to the task at hand, and to select the most practical combination of procedures. If the capital investment required to establish an operating facility is excessive, or if the time needed is too long, consideration should be given to having the work done, in whole or in part, by a qualified private-practice organization.

32. There is every reason to expect that in the near future more advances will be made in the surveying and mapping sciences which will cause even the procedures outlined here to be outmoded. For example, we can expect to see a practical instrument for automatic contouring, an economical process for analytical aerotriangulation, and the use of new sensing devices to replace or supplement optical photography so that haze, foliage and even clouds will no longer impede aerial surveying of areas currently blanked out by these obstacles. Through the sharing of knowledge of new developments as they occur, advances in the field of surveying-mapping can more quickly help to bring about a better life for people all over the world.

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[29] Army Map Service Bulletin No. 36, Edition 1-AMS, 6-15 (1959).

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